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A STUDY OF THE EFFECTS OF AGGREGATE FACTORS ON PAVEMENT FRICTION

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by

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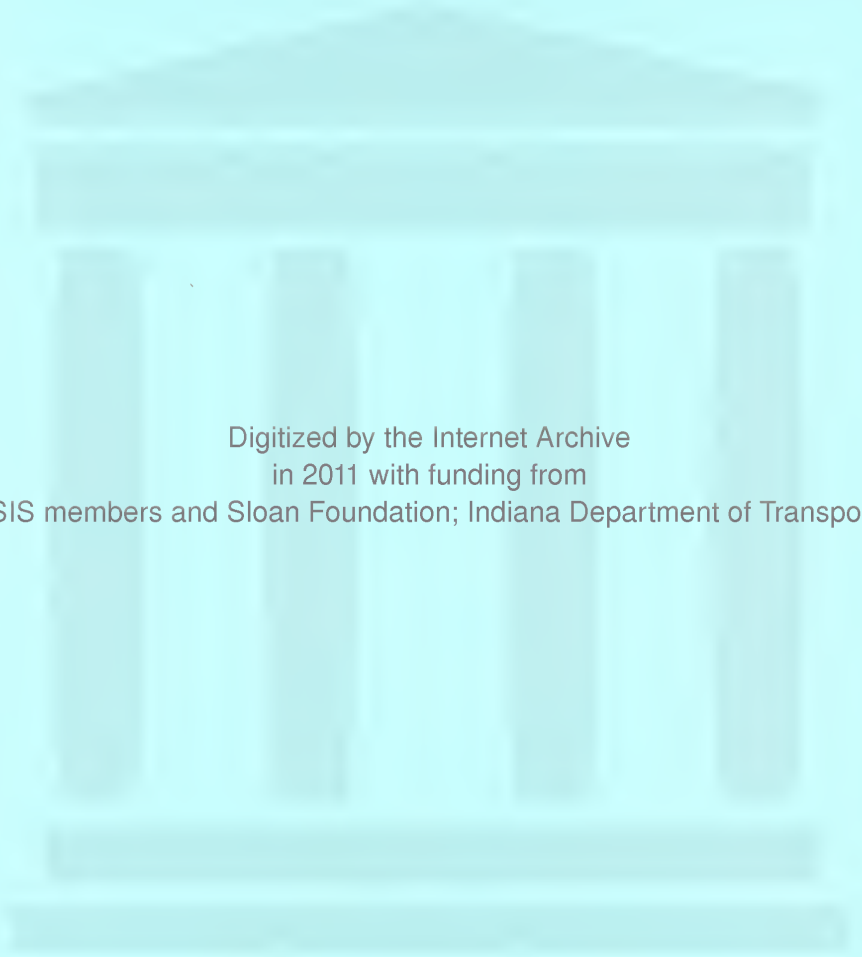

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Technical Paper

A STUDY OF THE EFFECTS OF
AGGREGATE FACTORS ON PAVEMENT FRICTION

TO: K. B. Woods, Director
Joint Highway Research Project

January 25, 1961

FROM: H. L. Michael, Assistant Director
Joint Highway Research Project

File: 9-6-10
Project: C-36-53J

Attached is a technical paper titled "A Study of the Effects of Aggregate Factors on Pavement Friction" by Jack E. Stephens and W. H. Goetz. This paper was presented at the Annual Meeting of the Highway Research Board in January 1961.

The material presented in the paper has been previously submitted to the Advisory Board in more detailed form. It was prepared in the attached summary form for publication and dissemination.

The technical paper is presented to the Board for the record and for approval for publication by the Highway Research Board.

Respectfully submitted,

Harold L. Michael

Harold L. Michael, Secretary

HLM:lmc

Attachment

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A STUDY OF THE EFFECTS OF AGGREGATE FACTORS ON PAVEMENT FRICTION

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SYNOPSIS

Even though the skidding resistance of pavements has been studied for many years, many questions concerning the true nature of the interaction of rubber and pavement surface remain unanswered. During field testing, the lack of control over many of the variables which are included in this problem has prevented the effective evaluation of individual factors.

For this reason certain tests were carried out by the authors on laboratory specimens which, while not greatly resembling pavements, were planned to eliminate many variables and thus aid in evaluating those which remain. Actual surface resistance measurements were made in the laboratory machine located at the Joint Highway Research Project at Purdue University.

Tests were conducted on surfaces planned in a manner to maintain a constant area of aggregate while varying the number and shape of edges. Although not exhaustive, several radically different shapes were included. For some of the specimens, the aggregate shapes used permitted controlled variation in the sharpness of aggregate edges.

A series of tests was performed in which the normal load was made the major variable. For any one specimen the aggregate area was constant. Additional specimens were tested in which the area of aggregate in contact with the test shoe was varied while the edges and test load were held constant. The rock cores used were a soft limestone and a durable sandstone.

The polishing rates of several different rocks were investigated. Skid-resistance tests were made on cores after successive polish cycles utilizing

crushed quartz as a polishing medium. The same cores also were tested after polishing with abrasive dust made from the core material.

Tests on rock cores as polished by different sizes of abrasives indicated that for a given rubber, an optimum size of roughness existed. Graded silica sand was used to make surfaces of different degrees of roughness in order to find this optimum size of roughness or texture for the rubber test shoes used.

INTRODUCTION

In recent years many pavement engineers have become concerned with the rapidity with which certain pavements have polished under the action of modern high-volume traffic. Several agencies have field-measurement programs underway in which skid resistance of pavements is evaluated. However, most field measurements do not aid greatly in furthering an understanding of the basic principles which contribute to this problem. Consequently, there has been a trend toward the increased use of laboratory-scale tests intended for determining the coefficient of friction or some other related property of pavement surfaces (1, 4, 5, 11, 13). Such tests, while possibly not representative of true field conditions, do have the advantages of lower cost, controlled conditions, and application to mixes not available on existing roads.

The studies presented in this paper were intended to penetrate into some of the basic factors present in skid-resistance problems. The test specimens were planned to provide information on certain factors which can not be isolated easily in field tests. In so doing the configuration of the aggregate pieces in the specimens necessarily departed from that in full scale pavements.

TEST PROCEDURE

The procedure followed for these tests, consisted of three basic steps. First, a surface specimen was mounted in a test ring from the skid resistance machine. Second, this surface was worn or polished to a degree which fitted the series under test. Third, measurements were made of the relative resistance value of the surface. The second and third steps were repeated several times on some of the test surfaces, when so doing added to the information obtained.

The actual method of performing the first step above was varied to accommodate the aggregate shape used. The continuous surfaces were prepared by sawing slices from 6-in. rock cores and mounting them in the test rings. The discontinuous surfaces were prepared by hand placing precut aggregate pieces in predetermined patterns and backing with mortar or bitumen. The controlled fine-textured surfaces were molded from sand-bituminous mixtures. The material was compacted into the rings to a true surface by means of a loaded vibrating plate. The first surface specimens were polished in the skid resistance machine in a manner similar to that used by Shupe and Goetz on coarse aggregate bituminous pavement specimens (11). This procedure consisted of holding a rubber polishing surface against the rotating specimen while water carried abrasive between the two surfaces. The resulting polish was controlled by varying both the abrasive used and the length of the polishing cycle.

This form of polishing left a circular pattern of minute striations on the solid-core surfaces. For this reason later surfaces were polished in the manner developed by the authors for fine bituminous surfaces (12). The

equipment consisted of a turntable on which the surface specimen turned freely and a flat, tread-rubber, polishing shoe 2 in. in diameter rotated by a drill press as shown in Figure 1. In use, the specimen was flooded with water charged with abrasive dust. A static load on the drill-press operating level pressed the rotating shoe against the slowly turning specimen. As the axis of rotation of the turntable was offset from that of the polishing shoe, an annular area large enough to accommodate the test shoe was polished. The pressure was held constant for all specimens, but both the nature and size of the abrasive dust were varied.

The actual skid-resistance measurements were made in the laboratory skid resistance machine developed by the Joint Highway Research Project at Purdue University (11). This machine consists of a power source arranged to rotate a flat, circular test specimen which is held in contact with a tread rubber test shoe. A schematic diagram of this equipment is shown in Figure 2. In operation, a test specimen is clamped into the powered chuck which is then rotated at a speed equivalent to 30 mph at the average radius. The test shoe is then pressed against the rotating surface by a normal force supplied thru the weighted lever system. Throughout the test/surface is flooded with water. The frictional torque transferred from the driven specimen to the test shoe is measured by a cantilever arm bearing SR-4 strain gages which activate an analyzer. The values read from the resulting oscillograph are in units of torque and give a convenient relative basis for comparisons of different surfaces.

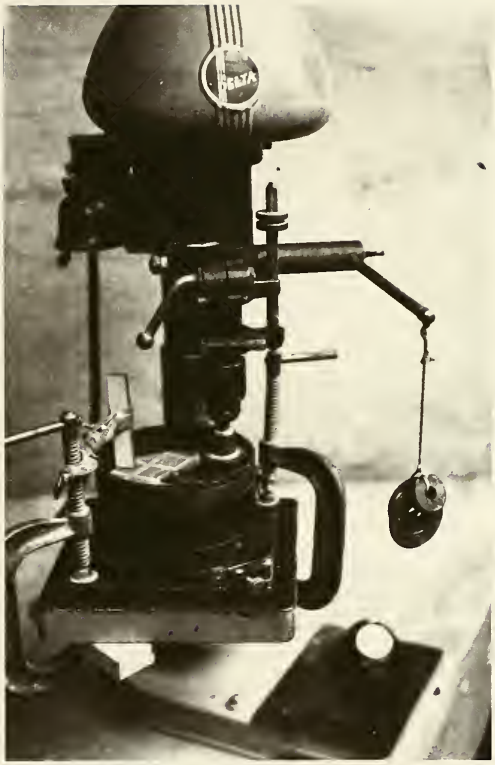


FIG. 1 DRILL PRESS SETUP FOR POLISHING

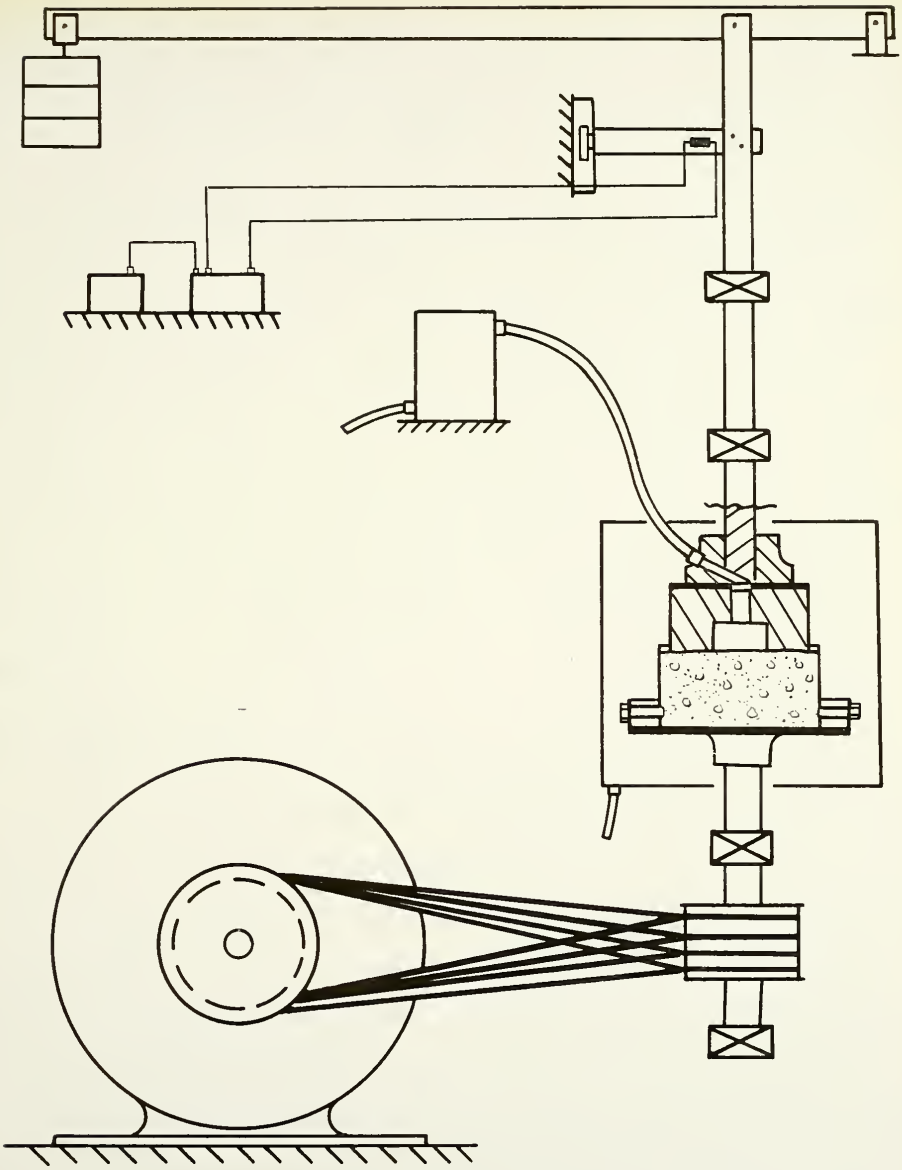


FIG. 2 SCHEMATIC DIAGRAM OF LABORATORY SKID-TEST APPARATUS

RESULTS

Several investigators have stated that friction between pavement and tires is made up of two major components (7, 8, 9). One component of the friction or skid resistance is that force required to overcome direct mechanical interference at the edges of the aggregate. This portion is affected by the hardness of the rubber, the width of the crevices between aggregate particles, and aggregate edge shapes. The second component is the friction between the surface of the aggregate and the sliding rubber surface. The magnitude of this portion of the friction is primarily a function of the nature of the two materials, speed of the relative motion, and the magnitude of the normal pressure.

Effect of Aggregate Edges

In order to show the effect of aggregate particle edges upon frictional resistance, several special specimens were prepared of similar surface aggregate area. The term "surface aggregate area" as used here refers to the total area of those faces of the aggregate which lie essentially in the plane of the pavement surface. This area can be readily determined for flat-surfaced aggregate but is somewhat indeterminate for round aggregate. It was intended to represent that area of aggregate touched by the sliding rubber test shoe. The first set of specimens consisted of three limestone cores. One end of each core was squared with a diamond saw. Radial slots were cut by means of the diamond saw across two of the cores. The first received 12 slots 0.32 inches wide. The second recieved 24 slots one-half as wide or 0.16 inches. Thus the

area of the two slotted cores was the same although the number of edges for the second was twice that for the first. The slotted cores appear as RS-8 and RS-16 in Figure 3. The third core received no special treatment.

These cores were first tested in an "as sawed" condition. They were again tested after a wearing cycle in the skid machine consisting of one minute with No. 000 crushed quartz as abrasive, one minute with No. 00000 crushed quartz, and one minute with mineral filler (limestone dust). A third test was made after a polishing cycle of one minute with mineral filler and 30 seconds with water only. See Table 1. The results of the last test were relative resistance values of 48 for the smooth core, 57 for RS-16, (24 slots) and 58 for RS-8 (12 slots). Thus, the creation of edges did increase the relative resistance values but the quantity of edges had little effect.

Similar solid and slotted cores were prepared from a hard sandstone obtained from Albion, New York. Table 1 shows that the relative resistance value of the solid sandstone after fine polish was 99, that of the core with 12 slots 76, and that of the core with 24 slots 72. Although the creation of edges reduced the relative resistance, the number of edges again seems unimportant. Increasing the slots from 12 to 24 did cause a further reduction in relative resistance, but not in proportion to that which resulted from the inclusion of the first 12 slots.

The cutting of slots in the surface reduced the area of stone in contact with the tread. Such a change in surface would be expected to cause a reduction in that part of the skid resistance or relative resistance which is due to surface friction. Cutting slots created edges or discontinuities in the surface which

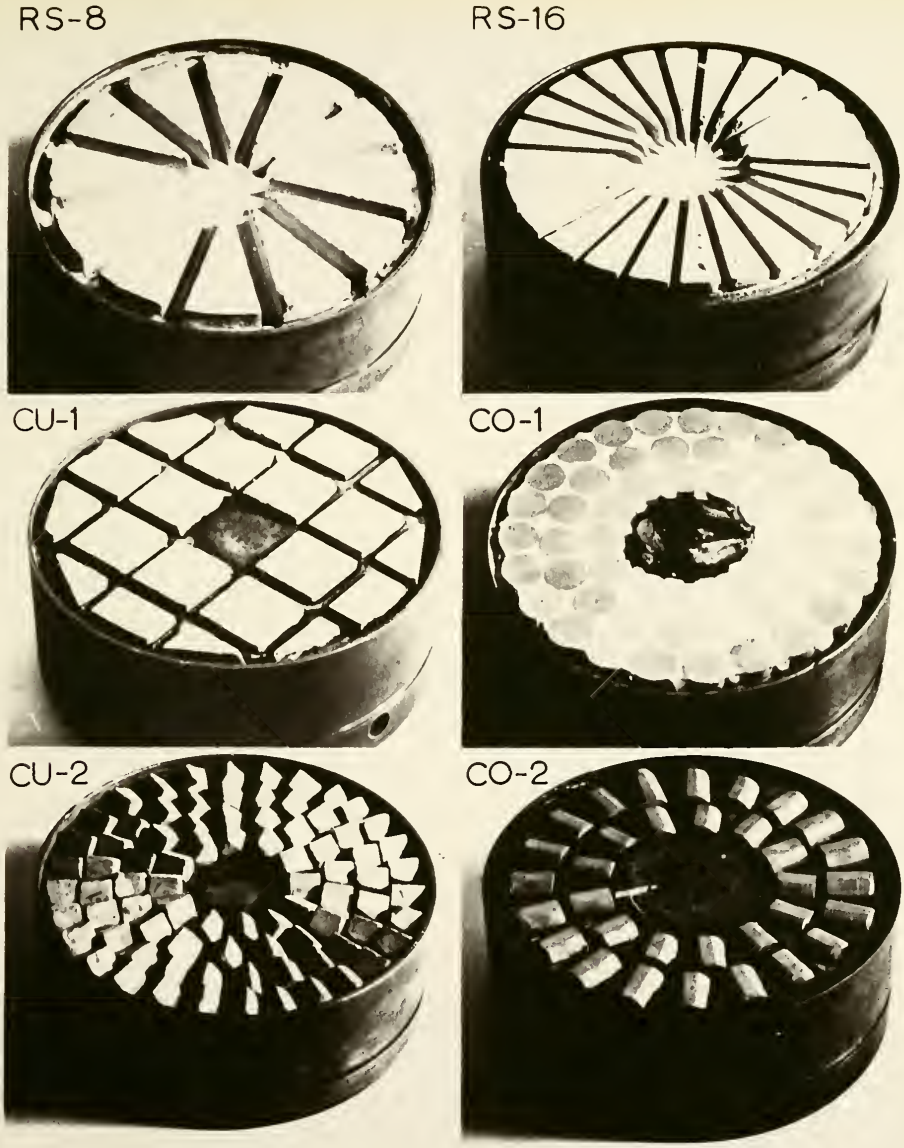


FIG. 3 SPECIMENS STUDIED FOR THE EFFECTS OF EDGES AND AREA ON SKID RESISTANCE

TABLE 1. Skid Resistance of Specimens with Variable Aggregate Edges

	Relative Resistance Value		
	As Sawed	Coarse Wear	Fine Polish
Greencastle Limestone			
Solid	46	34	48
12 Radial Saw Cuts (.32")	60	50	57
24 Radial Saw Cuts (.16")	55	48	58
Albion, N. Y. Sandstone			
Solid	108	87	99
12 Radial Saw Cuts (.32")	91	78	76
24 Radial Saw Cuts (.16")	88	74	72

Coarse Wear
Fine Polish -- As by Shupe and Goetz (11)

would cause that portion of the resistance due to edge interference to increase. The resistance created by a single edge is related to the width of void creating the edges. That is, the width of void space determines the depth to which tread rubber can penetrate and thus influences the magnitude of the resistance due to this edge.

Comparing the results from the limestone series to those from the sandstone series indicates that the effect of aggregate particle edges is related to the aggregate surface. A soft aggregate which polishes to a smooth surface is benefited by sacrificing area for edges. The directly opposite effect is found with strongly-textured aggregate such as sandstone. This would indicate that for maximum relative resistance value a limestone mixture should be designed for maximum edges, but a textured-aggregate mix should be designed for maximum aggregate area.

As further verification of this effect, specimen CU-1 composed of 1-in. squares and specimen CO-1 of 0.66 -in. diameter cores were prepared (Figure 3). At this stage of the tests the method of polishing the specimens was modified to avoid polishing in the same pattern as that used during testing. The solid limestone core and the slotted cores RS-8 and RS-16 were resurfaced in the diamond saw and polished by the new method using the drill press. These results are presented in Table 2. The relative resistance value for CU-1 was 50, the area was the same as for RS-8 and RS-16, and the edges were approximately those of RS-8 although not located radially.

The relative resistance value of CO-1 was 57. However, the area of stone in this specimen was approximately 15 per cent greater than that in RS-8,

TABLE 2. Skid Resistance of Surfaces Composed of Controlled-Shape Rock Fragments

Greencastle Limestone — Shoe Area 14.45 sq. in.

Test Load 463.72 poinds — Polished with No CCO crushed quartz

Specimen	Shape	Length of edges or radial dimension (in.)	Area of rock under shoe (sq. in.)	Contact Pressure (psi)	Relative Resistance Value: Aggregate Interstices Open — As Measured	Aggregate Interstices Open — Corrected to 28 psi	Aggregate Interstices Filled — As measured	Aggregate Interstices Filled — Corrected to 28 psi
CO-2	0.66 inch cores lying flat	20.64	0.0		28			
SO-2	as above	20.95	10.69	57	46	40		
CU-1	1 inch square cubes, flat, 1/4 in. spacing	18.8	12.11	50	50	46	46	45
RS-16	Solid core, 24 3/16 inch radial slots	36.0	12.1	50.3	50	46	44	43
RS-8	Solid core 12 3/8 inch radial slots	18.0	12.1	50.3	48	44		
CO-1	0.66 inch cores on end	25.85	14.01	43.4	57	53	52	51
CU-2	0.5 inch cubes on edge	30.5	0.0		67			
CU-2	as above	30.5	5.5	110	44	28		
SC	Solid core	0	18.85	32.1			44	43
Aluminum Cement	Solid surface	0	18.85	32.1			48	47

RS-16, or CU-1 and later work indicated such an increase in area would increase the relative resistance value approximately 4 units. Adjusting for this area factor would reduce the relative resistance value to 53. The fact that the area was greater than 12 sq. in. would also cause a reduction in contact pressure. Correcting the relative resistance value to terms of the same contact pressure would increase this adjusted relative resistance value to approximately 58. Thus, the more irregular voids of sample CO-1 were slightly more effective in creating resistance than the radial slots of specimens RS-8 and RS-16 and the edges of specimen CU-1.

In order to remove the effect of particle edges upon pavement friction, the interparticle space in the specimens referred to above (RS-16, CU-1, CO-1) were filled with plastic aluminum. See specimen CO-1 in Figure 3. After the aluminum had set, the surface was repolished with the same grade abrasive as used previously and the relative resistance value again determined. Plastic aluminum was used for this purpose as the relative resistance value for a surface of this material was 47, which was nearly the same as the limestone. Filling the interparticle spaces to eliminate edges reduced the relative resistance for all the surfaces, but the change was small. That for CO-1 fell from 57 to 52, for CU-1 from 50 to 46, and for RS-16 from 50 to 44. At the same time, the contact pressure decreased due to the greater area of contact. As shown by later tests, the small reduction in relative resistance value could easily be due to this factor. See Table 2.

Effect of Aggregate Area and Contact Pressure

As area of aggregate in the contact face seemed important, an additional specimen of small, 0.66-in. diameter, limestone cores was prepared. For this specimen the cores were placed with an element of the curved surface located radially in the test specimen as shown by CO-2 in Figure 3. Located in this manner the length of edges of the cores approaching the test shoe during a test remained constant regardless of the degree of wear of the cores. The first test of this sample was made before any polishing was carried out and the value obtained probably reflected this condition. For this first test the area of contact was uncertain as the rubber shoe rested on the curved surfaces of the cores and necessarily deformed until sufficient resistance developed to support the testing load. This implies contact for an appreciable area of each core rather than zero area.

After each relative resistance value measurement, the specimen was ground by means of a rubber shoe and abrasive dust (crushed quartz) to increase the flat area on the side of each core. Figure 3 shows this specimen when the flats had been ground until approximately 3/16 in. in width. The resulting relative resistance values presented in Table 3 have been plotted against area in Figure 4. The point on the zero area axis and possibly the next point are mis-located due to the uncertainty concerning area of contact for the cylindrical surfaces. As the area must necessarily be greater than zero, these two points should be moved to the right, possibly eliminating the reverse curve. If friction is a surface phenomena, for zero surface a relative resistance value of zero could be anticipated and for constant total load the relation between relative resistance value and area of aggregate would approach the broken curve- shown.

TABLE 3. Skid Resistance Test Results for Different Contact Areas Between Test Shoe and Limestone

Test load 463.72 lb. Shoe Area 14.45 sq. in.
Greencastle Limestone Polished with No. 000 Quartz

Specimen	Area Pattern	Area of rock under test shoe (sq. in.)	Pressure psi	Relative Resistance Value Measured	Relative Resistance Value Corrected to 28 psi
CO-2	0.66 inch dia. cores lying flat	no flat area		28	
		3.71	164.48	30	7
		4.53	133.5	31	10
		5.24	115.0	35	18
		6.16	98.0	38	24
		6.54	92.5	38	25
		7.20	84.0	41	30
		8.10	74.7	43	35
		8.63	70.0	44	36
		9.35	64.8	46	39
		10.69	57.0	46	40
CU-2	1/2 inch cubes on edge	no flat area		67	
		3.66	165.0	45	18
		5.5	110.0	44	28

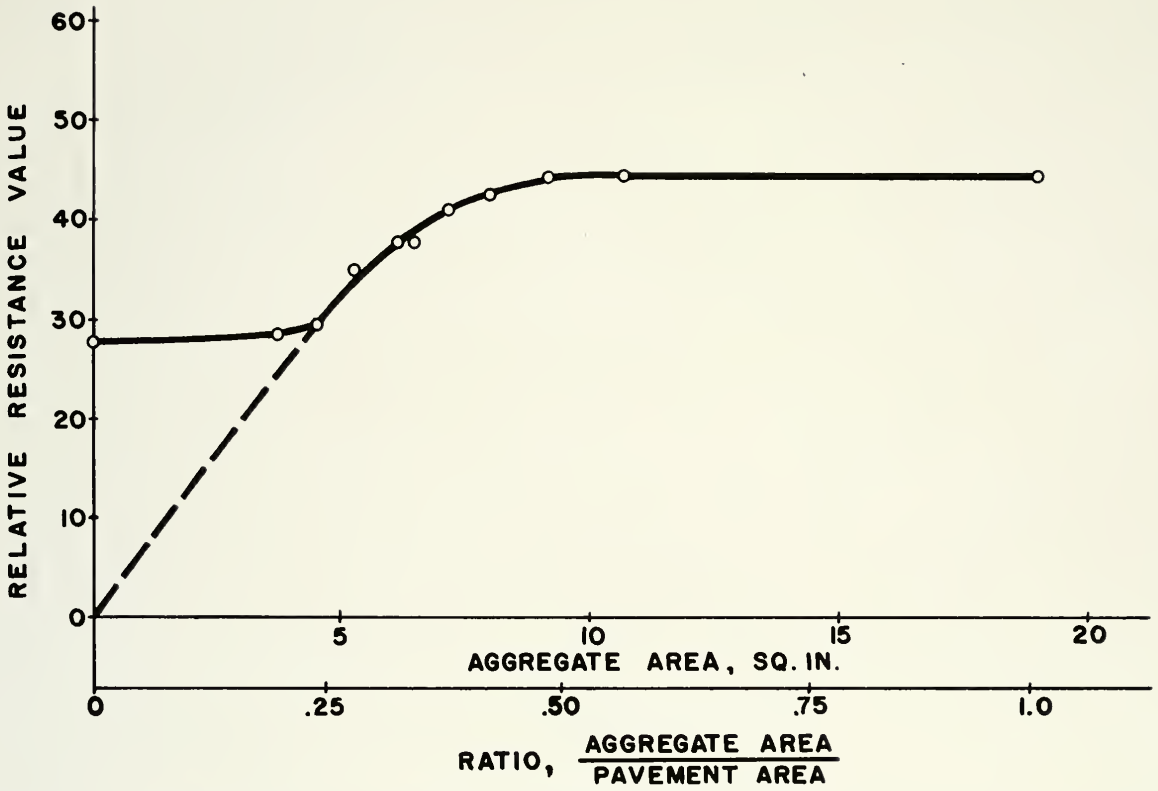


FIG. 4 VARIATION IN SKID RESISTANCE WITH RATIO OF AGGREGATE AREA TO PAVEMENT AREA (CONSTANT LOAD)

Using a constant load for tests of different area of aggregate caused the contact pressure to vary. Tests were conducted on certain specimens in order to establish the relation between contact pressure and relative resistance value. The results, as given in Table 4 and shown in Figure 5, establish a rate of increase in relative resistance value with increase in contact pressure. Under dynamic test the rate of increase for limestone, whether a solid core or fragments, is nearly constant at 1/3 of a relative resistance value point for each pound per square inch change in contact pressure.

Applying this contact pressure factor to the data of Figure 4 modified the curve somewhat. In Figure 6, area has been plotted against relative resistance value computed for constant pressure. The curve defined by the small triangles corresponds to that in Figure 4. For the small contact area portion of this curve, the angle at which the edges of the cores met the surface was very small. It could be expected that as the corners became sharper, the relative resistance value would increase. The second curve, defined by circles in Figure 6, shows the variation in edge angle with change in area. This angle increases slowly in the range of areas where relative resistance value increased rapidly. This nearly complete reversal of effect seems to indicate that the increased sharpness of the edges is not responsible for the increase in relative resistance value. To show that increase in area is as important as change in edges, several specimens were prepared of 1/2-in. cubes of limestone hand set with one edge located radially in the specimen surfaces (CU-2 in Figure 3). Data for these tests are included in Table 3. When skid tests were made on these surfaces prior to any wear or polish, the sharp edges of the

TABLE 4. Relative Resistance Values at Different Pressures for Greencastle Limestone and Medina Sandstone

Solid Limestone Core, Contact Area = 14.45 in^2		Solid Sandstone Core, Contact Area = 14.45 in^2		Multiple Limestone Cores, Contact Area = 8.2 in^2	
Pressure (psi)	Relative Resistance Value	Pressure (psi)	Relative Resistance Value	Pressure (psi)	Relative Resistance Value
		Static			
16.7	67	16.7	36	29.7	47
24.6	86	24.6	50	43.3	58
32.2	110	32.3	76	56.8	80
44.5	130	44.5	128	77.5	120
54.0	150	54.0	158	95.5	152
65.0	170	65.0	192	114.5	195
		Dynamic (2,500 rpm)			
16.7	15	16.7	30	29.7	28
24.6	24	24.6	45	43.3	35
32.3	27	32.3	59	56.8	38
44.5	30	44.5	74	77.5	49
54.0	32	54.0	87	95.5	55
65.0	35	65.0	102	114.5	59

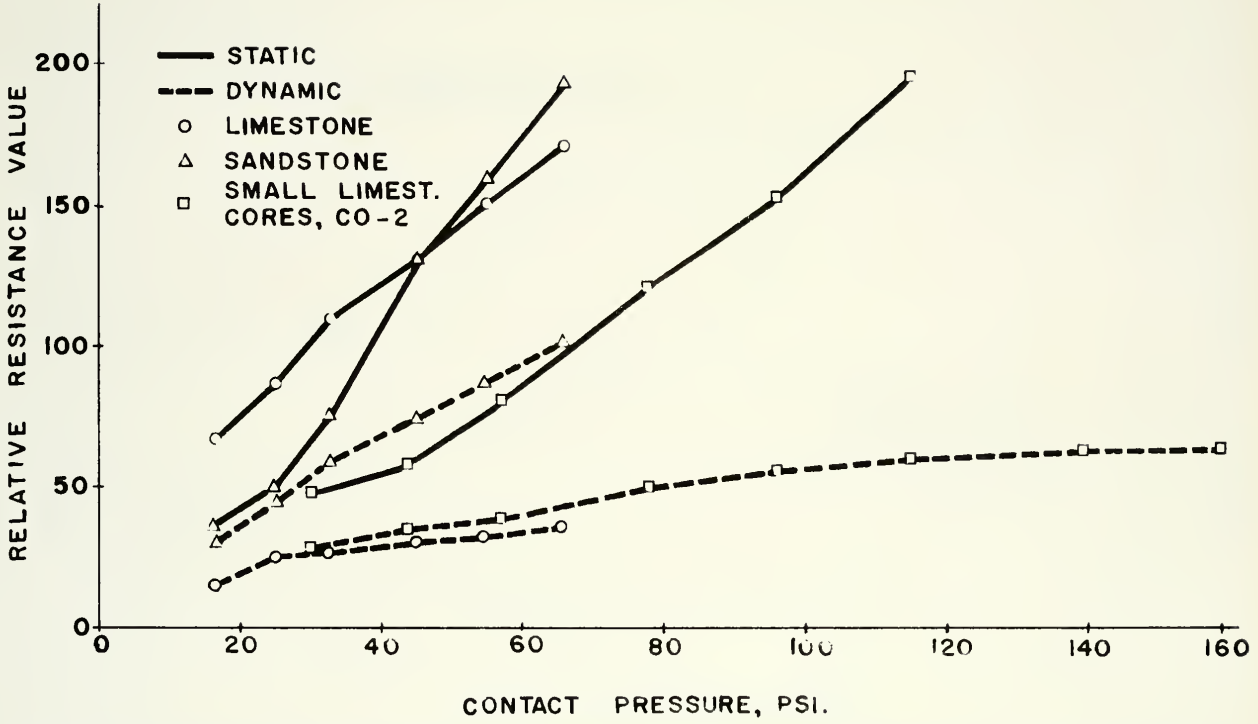


FIG. 5 VARIATION IN SKID RESISTANCE WITH CONTACT PRESSURE ON LIMESTONE AND SANDSTONE

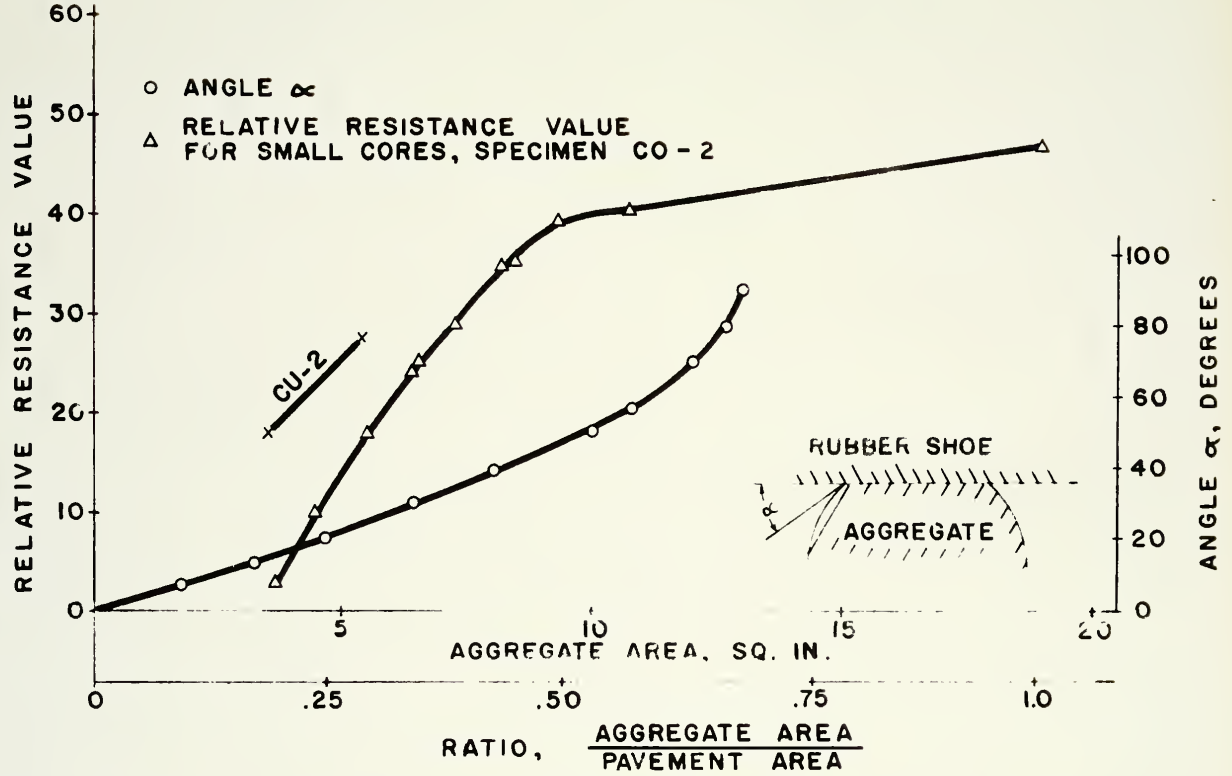


FIG. 6 VARIATION IN SKID RESISTANCE WITH RATIO OF AGGREGATE AREA TO PAVEMENT AREA (CONSTANT PRESSURE)

cubes bit into the rubber test shoe and shredded the surface. This extreme edge effect resulted in a relative resistance value of only 67. Grinding the surface of the specimen made from the cubes caused flat areas to develop without causing any change in the edges. The relative resistance value was obtained for only two degrees of wear. The extreme angularity of the cubes caused excessive chatter both during the test and polishing and the cubes were pulled out of most of the specimens. The two points after wear secured for CU-2 indicate the trend which can be expected. It is interesting to note that although the extreme sharpness of the cubes decreased with wear the actual relative resistance values corrected for pressure increased.

The relative resistance values obtained for the cubes in specimen CU-2 when the worn area was 3.66 sq. in. and 5.5 sq. in. were essentially the same (Table 3). However, the contact pressure in the second case was only 2/3 of that for the first. After computing relative resistance values corrected to a uniform contact pressure, the two points were added to Figure 6. With no change in edges, an increase in area caused an increased relative resistance value. For the same area CU-2 gave a higher value than did CO-1. Comparisons can only be made at small areas where the angle at which the edges of CO-2 met the surface was nerely zero, yet the points plotted would project the curve for CU-2 in much the same form as that for CO-2.

The effect of pressure was investigated further by comparing two materials, different shapes of particles, and both static and dynamic friction. Data for these tests are presented in Table 4. The limestone solid core and the small limestone cylinders compared well under dynamic test. The relative

resistance value has been plotted against contact pressure in Figure 5. At each pressure, the value for the small cores is slightly above that for the solid core and thus reflects the effect of discontinuity of the surface. Static relative resistance values for both limestone specimens are well above the dynamic values. The variation in value with pressure was a modest 0.3 units per pound per square inch change under dynamic conditions but increased to 1.8 units for static conditions.

For dynamic conditions both the actual value and the rate of increase of relative resistance are greater for the sandstone core than for the limestone. As the surface texture of the sandstone has more relief than the limestone, the greater actual value would be anticipated. The greater rate of change in relative resistance value with increased pressure can be explained by realizing that at low pressure the rubber will rub on only the tips of the texture of the sandstone surfaces; at higher pressures the rubber will deform into the texture and give increased resistance. Under static conditions the relative resistance value for sandstone increased sharply with increases in pressure. Although at low pressures the sandstone showed lower values than limestone, the rapid increase in values for sandstone made it superior at pressures above 43 lb. per square inch.

The surface texture of the stone can logically explain the variations shown in the curves of Figure 5. The texture of the surface of the sandstone was deeper than that of the limestone. Under static conditions an increase in pressure caused the rubber shoe to crowd down into the texture and to increase the sliding friction. The importance or magnitude of this effect depends on

the texture available to the rubber. Under dynamic conditions, the hysteresis character of the rubber prevents the full penetration of the rubber into the texture. That is, the rubber surface does not have time to rebound completely into a low texture area before being deformed upwards by the next high texture point. Therefore, the relative resistance value for dynamic conditions must always be lower than that for static conditions. The magnitude of this difference must then depend on the texture, which in reality controlled the degree to which the rubber penetrated the surface under static test.

This approach implies that for each rubber and speed of test, there is an optimum texture of surface which will give the best friction between the two. At a later point in this paper, limited tests intended to explore the possibility of finding an optimum size of crushed quartz for the rubber used are reported.

Effect of Abrasive Type

For all of the early tests of rock cores, the surfaces were polished by crushed quartz. In actuality most field pavements must be polished by traffic and abrasive dust provided by the road surface. That is, the abrasive present will be of the same character as the aggregate. Therefore, several cores were polished with the use of abrasives from the same source as the cores. The polishing cycles for each specimen started with abrasive passing a No. 30 sieve and retained on a No. 50 sieve and progressed into finer abrasives. Each cycle consisted of 15 minutes with one size abrasive under the compound action of the polishing shoe in the drill press. All of the cores responded to polishing with the core material in much the same manner.

At first the relative resistance value, Table 5, appeared to increase as polishing progressed, but a definite down trend appeared with further reduction in abrasive size. All four cores represented by Figure 7 are limestones but include a wide range of crystalline structure as shown by Figure 8.

The curves can best be explained by realizing that an abrasive of the same material as the core would, in coarse sizes, tend to gouge the softer portions of the matrix and thus expose the individual particles of the structure. Polishing with particles as small or smaller than the rock structure would tend to actually wear or reduce the individual crystals. This would result in smaller but more frequent peaks in the surface texture.

In comparison, the crushed quartz abrasive when employed in a similar sequence, caused a down trend in relative resistance value throughout the series, as shown by the data in Table 5 and by Figure 9. The quartz was harder than any of the limestones and would reduce the surface texture for all of the sizes employed. It is notable that the quartz did not cause as rapid a decline in relative resistance value for the sandstone as for the limestones. As the quartz nearly approximates the sandstone in hardness, the curve for sandstone could be included in Figure 7.

Effect of Aggregate Texture

The outstanding performance of sandstone as shown in Figure 9 and the proven superiority of Kentucky rock asphalt as a full scale pavement seemed to indicate interesting possibilities in synthesizing similar material. Also it appeared desirable to determine if an optimum size of surface texture for maximum skid resistance could be shown by this means. In order

TABLE 5. Relative Resistance Values Resulting from Varying the Degree of Polish of Stone Cores

15-minute polish with each abrasive listed below	Relative Resistance Values				
	Sandstone Medina, New York	Limestone Greencastle, Indiana	Limestone Wheeling, W. Virginia	Limestone Richmond, Indiana	Dolomite Bedford Penn
No. 2 quartz	79	55	45	68	54
No. 2 quartz	87	52	46	67	52
No. 1 quartz	87	52	37	66	53
No. 1 quartz	87	46	34	60	48
No. 00 quartz	80	46	44	60	63
No. 00 quartz	79	48	42	60	60
No. 000 quartz	80	47	45	47	62
No. 000 quartz	78	45	40	44	60
No. 00000 quartz	78	38	37	40	57
No. 00000 quartz	78	40	37	43	58
Limestone Mineral Filler	78	31	29	39	52
Limestone Mineral Filler	77	27	27	38	48
Abrasive Material same as core, sieve size fractions					
No. 30 - No 50		48	46	65	72
No. 30 - No 50		43	55	70	65
No. 50 - No 100		47	54	65	81
No. 50 - No 100		49	57	65	78
No. 100 - No 200		53	60	65	84

TABLE 5. Continued

No. 100 - No 200	51	58	63	83
No. 200 - No 270	50	61	55	78
No. 200 - No 270	35	41	41	61
No. 270 - Finer	29	42	38	60
No. 270 - Finer	23	46	37	58

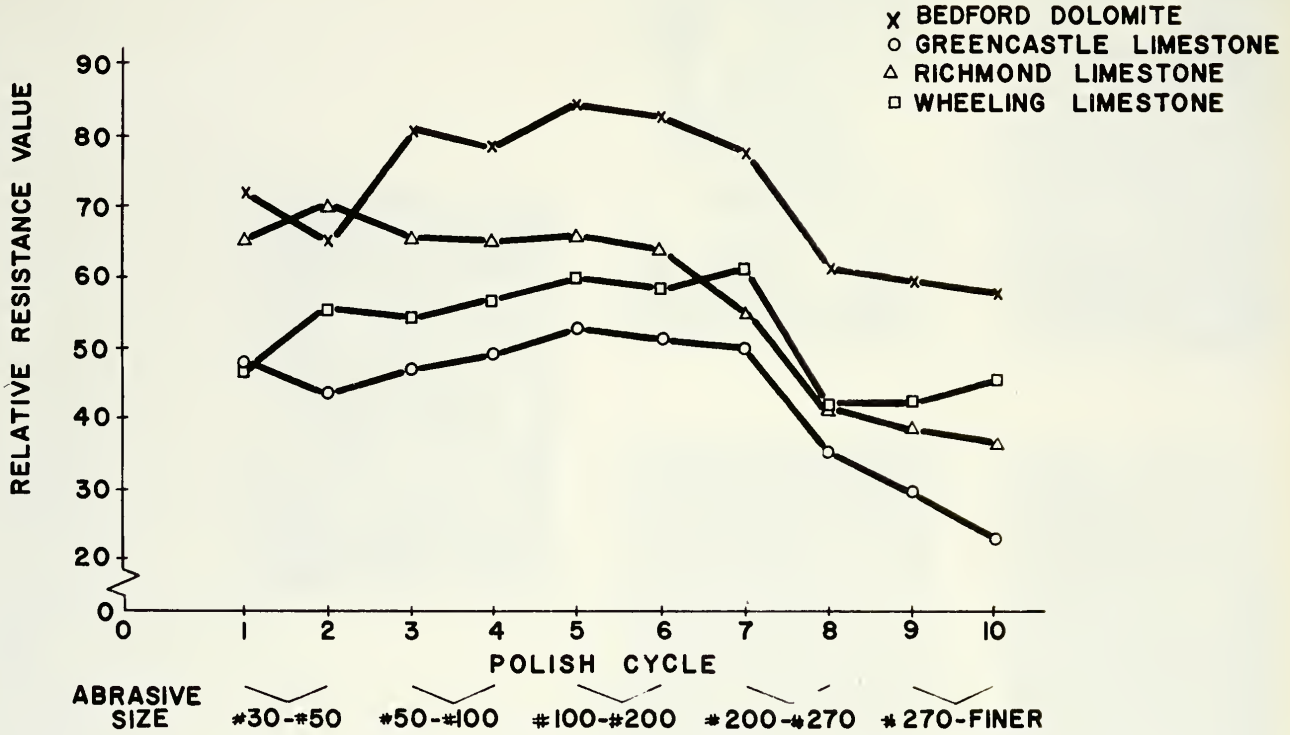
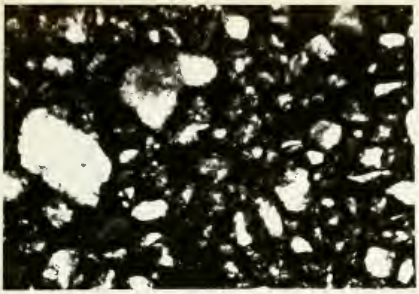


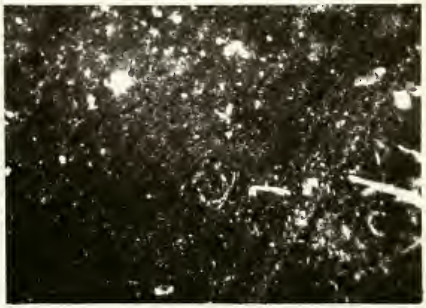
FIG. 7 VARIATION IN SKID RESISTANCE WITH POLISHING CYCLE FOR ROCK CORES (CORE MATERIAL AS ABRASIVE)



MEDINA SANDSTONE

BEDFORD DOLOMITE

RICHMOND LIMESTONE



WHEELING LIMESTONE

GREENCASTLE LIMESTONE

FIG. 8 PHOTOMICROGRAPHS OF THIN SECTIONS OF ROCK CORES (90X)

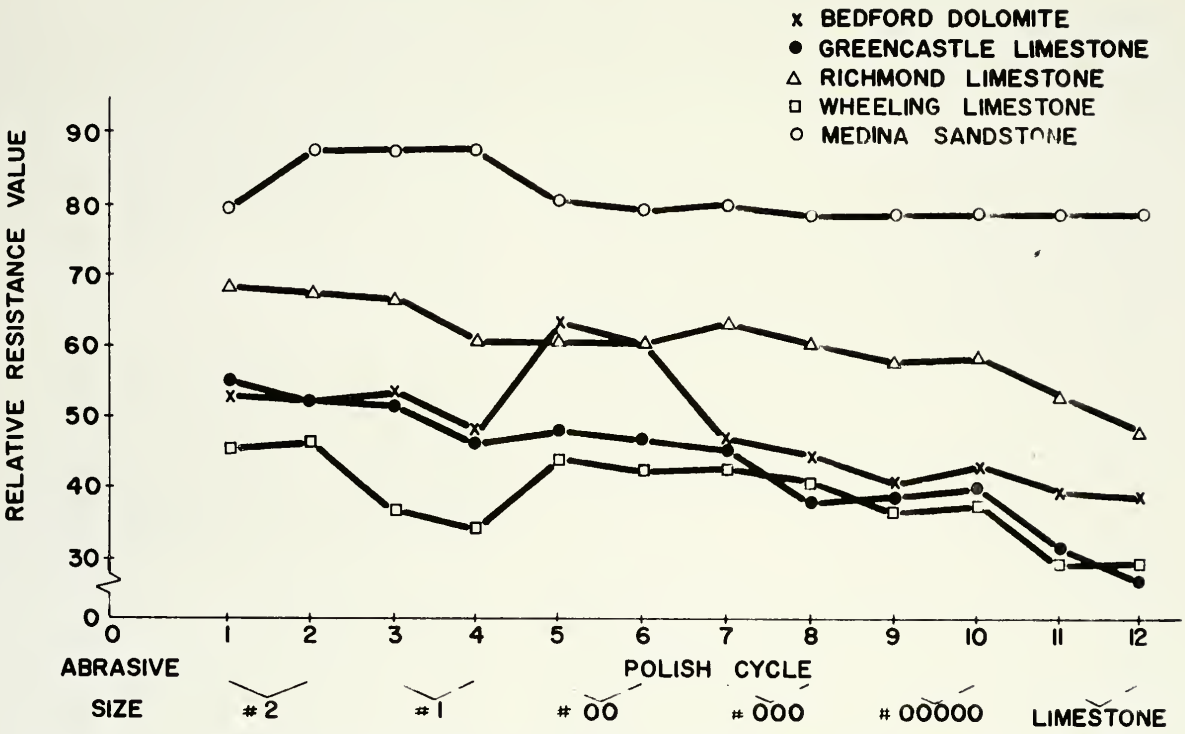


FIG. 9 VARIATION IN SKID RESISTANCE WITH POLISHING CYCLE FOR ROCK CORES (CRUSHED QUARTZ FOR ABRASIVE)

to take advantage of the widest range of particle sizes possible, the crushed silica originally intended for use as a polishing abrasive was selected as aggregate for one series of specimens. This gave sizes from that passing a No. 30 sieve and retained on a No. 50 to passing a No. 270 and retained in the pan. Using three adjacent sizes of aggregates, a series of fine-textured bituminous surfaces were prepared and tested. The results are listed in Table 6 and shown by solid lines in Figure 10. The different solid curves resulted from tests "as rolled" and after two different degrees of polish. The optimum relative resistance value was obtained for the mix of 70% - No 30 to No 50, 15% - No. 50 to No. 100 and 15% - No. 100 to No. 200. As the largest part of this mix would be particles approximately 0.0175 in. in diameter, the size of asperities to be expected on this surface would be 0.0088 in. high spaced at 0.0175 in.

Repeating the same procedure with naturally rounded silica sand gave a somewhat different result. The results obtained are shown graphically as broken lines in Figure 10. Surprisingly, there was little spread in the results for the different degrees of polish. Also, it is interesting to note that the maximum relative resistance value obtained in this series was for the rounded aggregate. Regrettably, shortages of extremely fine round particles prevented extending the round series until an optimum had been passed. The maximum reached was for the round mixture based on 0.0088 in. diameter particles. A texture of 0.0044 in. height spaced at 0.0088 in. can be expected from this size.

TABLE 6. Variation in Relative Resistance Value of Fine Bituminous Surfaces with Reduction in Size of Aggregate.

Specimen	Aggregate	Shape	Gradation, % of Total Aggregate									Fineness Modulus	Asphalt, % of Aggregate	Relative Resistance Value		
			#4 - #8	#8 - #16	#16 - #30	#30 - #50	#50 - #100	#100 - #200	#200 - Finer	#000 Quartz	#00000 Quartz			As Rolled	1 Polish	2 Polish
H-1	Silica Sand	Natural	70	15	15							5.55	6½	60	56	58
H-2				70	15	15						4.55	6½	77	75	79
H-3					70	15	15					3.55	6½	81	79	79
H-4						70	15	15				2.55	7½	91	94	90
H-5							70	15	15			1.55	8½	102	97	108
E-1		Crushed	70	15	15							5.55	6	81	75	75
E-2				70	15	15						4.55	6	84	77	72
E-3					70	15	15					3.55	6½	93	79	73
E-4						70	15	15				2.55	7	102	89	79
E-5							70	15		15		1.55	7½	92	73	108
E-6								70		15	15	0.70	10	53	35	40

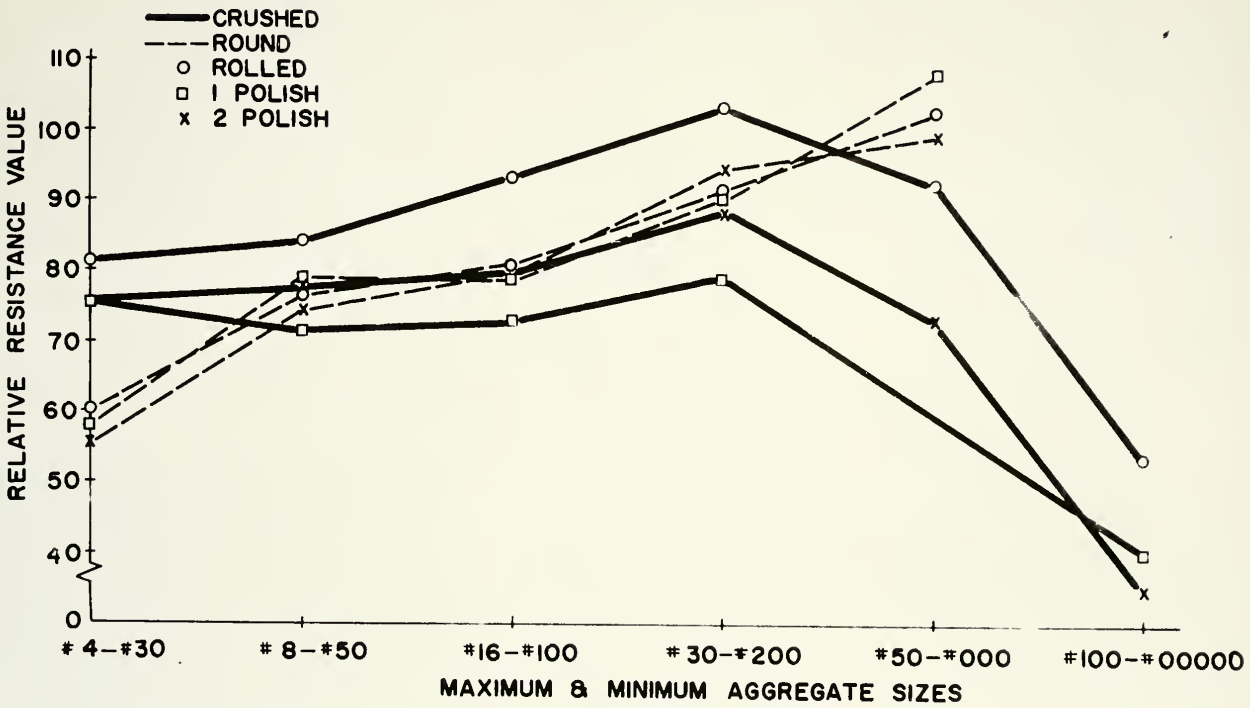


FIG. 10 VARIATION IN SKID RESISTANCE WITH AGGREGATE SIZE FOR FINE BITUMINOUS MIXTURES COMPOSED OF ROUND AND ANGULAR SILICA SAND

SUMMARY

Tests performed on surfaces of controlled shape aggregate particles gave general indications of the relationship between the effect of particle edges and particle surfaces. The contribution of the edges to the relative resistance value of larger, smooth aggregate particles was a small increase in resistance. The creation of edges in boldly textured aggregate reduced the relative resistance value.

Area of aggregate exposed in the surface of the specimen and thus available to the rubber shoe for friction had a major effect on the relative resistance value. The greater the ratio of aggregate exposed to the total surface area, the greater the relative resistance value. The rate of this trend was strongest for low ratios, moderated as the area of aggregate approached one-half of the test surfaces, and remained nearly constant thereafter.

Several specimens tested under various pressures showed increases in relative resistance value with increased contact pressure. For coarse aggregate pavement, the rate of increase was dependent on material rather than on aggregate shape. This rate was greater for strongly-textured stone such as sandstone than for soft material such as limestone.

The use of different abrasives for polishing rock cores prior to relative resistance value tests indicated that the degree of polish attained for a given effort is a function of both the rock from which the core was cut and the abrasive used. The use of an abrasive which was harder than the cores, caused a continual reduction in relative resistance value as the size

of abrasive was reduced. The use of abrasive identical with the cores established that for each material therewas a definite size of similar abrasive which gave the surface a polish resulting in the highest relative resistance value. For the limestones used in this study, the abrasive size which resulted in the highest relative resistance value was that passing a No. 100 sieve and retained on a No. 200 sieve.

Bituminous mixtures using crushed and round silica sand were used to establish the size of granular surface texture which resulted in the highest relative resistance value. For crushed silica this size was 0.0175 inches in diameter. For round silica, a size below 0.0088 inches was indicated.

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